RESEARCH DEPARTMENT

A meter for the assessment of drop – outs in video tape recording

TECHNOLOGICAL REPORT No. EL – 6

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THE BRITISH BROADCASTING CORPORATION
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W.K.E. Geddes, M.A. (Cantab.)

D. Maurice

for Head of Research Department

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SUMMARY

The report describes the design and application of a meter which records, on a paper chart, the subjective impairment due to drop-outs in a replayed video tape recording. The meter measures the envelope of the recovered r.f. signal and derives the subjective assessment by means of a simple analogue circuit which embodies the results of a series of viewing tests. As an additional facility, the meter can simultaneously register, on the same chart, the audio sensitivity of the tape under test.

1. INTRODUCTION

During the playback of video tape recordings, momentary loss of the reproduced signal takes place as a result of microscopic blemishes on the tape. Typically, the loss lasts for five or ten microseconds and occurs sporadically, and perhaps ten or twenty such events occur in each minute of recorded programme. This phenomenon is known as "drop-out" and gives rise to horizontal flecks in the displayed picture; these may be black, white or "noisy" according to the replay characteristics of the video tape recorder.

The drop-out content of each new tape is assessed as part of its acceptance tests and, hitherto, this has been carried out by visually monitoring the replay of a black-level signal recorded on the tape. The meter described in this report has been developed in order to allow the assessment of drop-outs to be carried out more economically and more consistently.

It has been established, by an extensive series of tests[1], that the subjective impairment produced by drop-outs can be assessed from the output of a simple analogue circuit supplied with an input describing both the duration of drop-outs and the rate of their occurrence. Thus, the varying output of the analogue circuit represents the varying degrees of annoyance experienced by a viewer watching a programme. The practical drop-out meter described in this report is based on this analogue circuit; the output from the circuit is recorded on a paper chart, thereby providing a convenient record of drop-out content for the whole length of the tape.

The drop-out meter is mainly used for acceptance testing of new tapes. A further characteristic of tape that must be examined is the constancy of audio-track sensitivity throughout its length. Means for assessing audio sensitivity* have therefore been added to the drop-out meter, the two results being recorded on the same chart during a single playing of the tape.

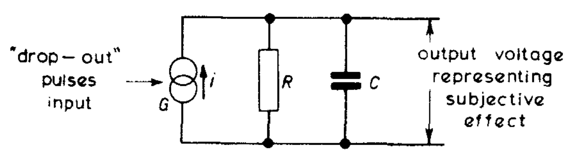

Fig. 1 - Analogue Circuit

2. DESCRIPTION OF THE METER

2.1. Design Philosophy

The analogue circuit upon which the meter is based is shown in Fig. 1. Each drop-out causes the current-pulse generator *G* to produce a quantity of charge that increases (though not linearly) with the duration of the drop-out. Application of this charge to the parallel circuit *RC*, which has a time constant of about fourteen seconds, produces a voltage bearing a known (although non-linear) relationship to the subjective impairment of the picture expressed in terms of a six-point grading scale.**

* Devised by Mr. D.N. Gregory of Television Recording Department.

** 1. Imperceptible (no impairment)
2. Just perceptible (negligible impairment)
3. Definitely perceptible but not disturbing (slight impairment)
4. Somewhat objectionable (marked impairment)
5. Definitely objectionable (severe impairment)
6. Unusable (complete impairment)

It will be appreciated that the impairment produced by a given drop-out content is dependent upon the type of picture within which it occurs. No prediction of a tape's acceptability made before a programme is recorded on it can, therefore, be entirely reliable, whatever the method used. However, the meter is based upon average subjective gradings obtained from a variety of pictures, and this reduces uncertainty to a minimum.

It was decided that the output of the analogue circuit should be registered on a moving paper chart provided with a time scale, in order to show the distribution of drop-out content throughout the length of the tape. The section of tape responsible for an observed feature on the chart can thus be located with the aid of the "elapsed time" meter on the video-tape recorder. By showing the disposition of bad portions of an otherwise good tape, the chart can also facilitate a decision as to whether it is practicable to save the tape from rejection by cutting out the bad portions. In order to avoid the production of unmanageably long charts, the chart speed is as slow as is consistent with preserving adequate detail; the speed of twelve inches (thirty centimetres) per hour that is used in practice has been found satisfactory in both respects.

The meter detects the presence of a drop-out as a fall in the amplitude of the frequency-modulated replay signal. During a drop-out this signal, though attenuated, may still be sufficient to ensure satisfactory demodulation. The performance of individual machines may differ, so there is some latitude in defining the degree of amplitude reduction constituting a drop-out. However, a typical value of this important parameter of the meter, which will be referred to as the "critical drop", may be taken as 20 dB. Since the recorder's amplitude limiter* may suppress reductions of this order, the signal fed to the meter must be extracted from a point in the replay chain that precedes the main amplitude-limiting circuits but follows combination of the outputs from the four heads. A suitable signal is available from the output of the head switcher.

It was established during the survey described in Reference 1 that the subjective effect of a drop-out depends upon its spatial extent on the displayed picture and that a drop-out of given duration produces a degree of impairment that increases with the line-scanning frequency of the television standard in use. A drop-out meter must therefore include provision for changing its assessment of drop-outs according to whether the tape being tested is required for use exclusively for 405-line signals or whether it must also be suitable for 525- and 625-line signals. It should be stressed, however, that the adjustment of the meter is determined solely by the scanning-standard of the signal which will be eventually recorded on the tape and not by the standard used for the test.

* An Ampex 1000 series recorder will be assumed throughout this discussion.

It has been considered advisable to include a calibrator as an integral part of the meter so that the performance can be checked without the need for specialised apparatus.

The practical meter described in this report is calibrated in accordance with the subjective results obtained for peak-white drop-outs. It was found that when the drop-outs are black, about three times as many drop-outs can occur for a given degree of impairment. Thus it would be permissible to interpret the meter's readings more generously if it were known that the tapes being tested would be replayed exclusively on machines producing black drop-outs. No tests were made with "noisy" drop-outs, but from qualitative observation they appear to produce a degree of impairment more typical of black drop-outs than of white ones. Fig. 2 shows the relationship between the deflection of the chart recorder and the subjective impairment grading. Full-scale deflection has been arranged to correspond to a grading of 3·0, because higher degrees of impairment are not of sufficient interest to justify cramping that part of the scale embracing the acceptable/unacceptable threshold.

2.2. Functions Performed by Meter

Any meter embodying the design philosophy outlined above must perform the basic functions

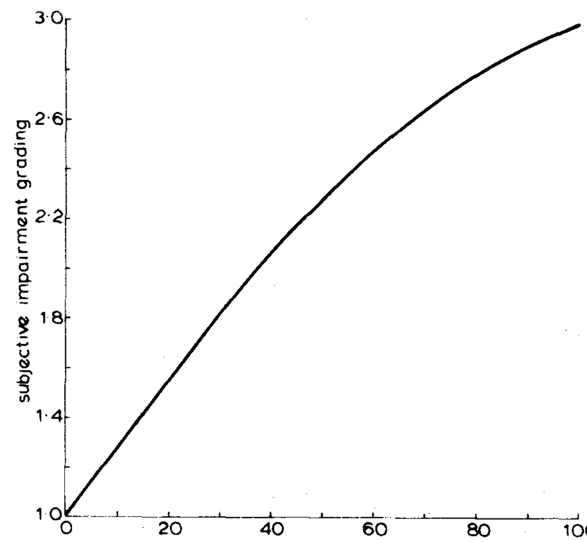

Fig. 2 - Chart-recorder calibration curve

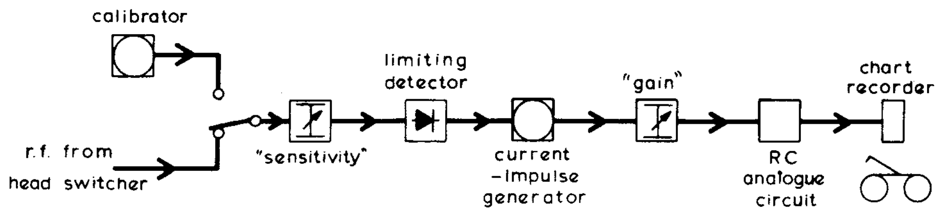

Fig. 3 - Functional diagram of drop-out meter

shown in Fig. 3. The current-pulse generator (corresponding to "*G*" in Fig. 1) must be actuated whenever the r.f. input to the meter falls from its normal value by more than the "critical drop" in the amplitude of replay signal chosen as defining a drop-out; it is therefore necessary to control this generator, as shown, by means of some form of limiting detector whose output is constant for all input levels above a certain critical level, but falls abruptly to zero whenever the input level is reduced below the critical value. The "sensitivity" control is adjusted so that the input level to the detector reaches its critical value when the normal r.f. level from the v.t.r. decreases by the critical drop.

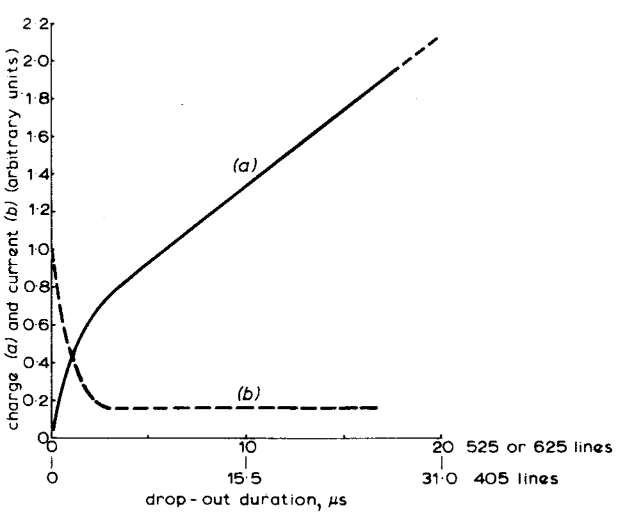

Fig. 4 - Output of current-pulse generator as a function of drop-out duration

Each drop-out must cause the current-pulse generator to produce a charge appropriate to its duration. The required relationship between duration and charge, derived from the subjective survey, is shown as curve (*a*) in Fig. 4. This relationship is obtained if the current, *i*, (see Fig. 1) declines from an initial peak during the first part of each drop-out and then maintains a constant value for the remainder of the drop-out, in the manner shown by curve (*b*) of Fig. 4.

The "gain" control shown in Fig. 3 between the current-pulse generator and the analogue circuit is used, in conjunction with the calibrator, to secure a standard deflection of the chart recorder from a standard sequence of simulated drop-outs. The calibrator provides an r.f. signal that is repetitively interrupted for a period equal to the duration of a typical drop-out. The frequency of these interruptions is chosen to produce an impairment grading somewhere near the centre of the range covered by the meter. In order to calibrate the meter, the signal from the calibrator is substituted for the signal from the v.t.r., and the "gain" control adjusted until the reading on the chart recorder corresponds to the known grading.

The direct connection from the analogue circuit to the chart recorder, shown in Fig. 3, must be replaced by more complex arrangements if an indication of audio sensitivity is to be combined with the indication of drop-out impairment at the input to a single-channel chart recorder; these arrangements are described, for the practical meter, in the next Section.

Circuit details of the practical meter are given in the Appendix.

2.3. The Audio-Sensitivity Facility

The audio-sensitivity signal is derived quite straightforwardly by detection of replayed 1 kHz tone. Combining the audio and drop-out signals on the same chart, however, necessitates some additional circuits. The chart recorder used is of the "sampling" type and records one sample every five seconds by pressing a small stylus, carried on the pointer of a moving-coil meter, against a pressure-sensitive paper chart, thereby making a small dot; thus, if the detected audio signal and the drop-out impairment waveform (Waveform 6b of Fig. 8) were sampled alternately, each would be sampled every ten seconds. The drop-out impairment waveform, however, decays between drop-outs with a fourteen-second time-constant, and the peak produced by an isolated burst of drop-outs could thus decline to half its maximum value before being sampled. It is therefore arranged that the chart recorder does not sample the impairment waveform directly, but registers the peak value attained by that waveform during

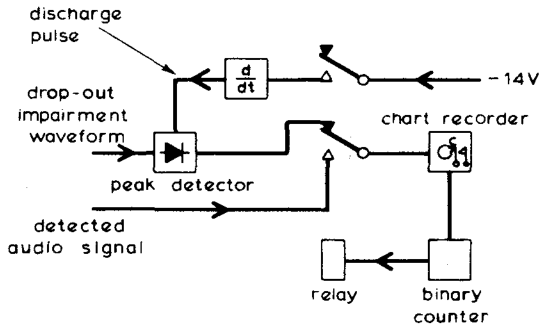

Fig. 5 - Schematic diagram of arrangements for combining "audio" and "drop-out" signals

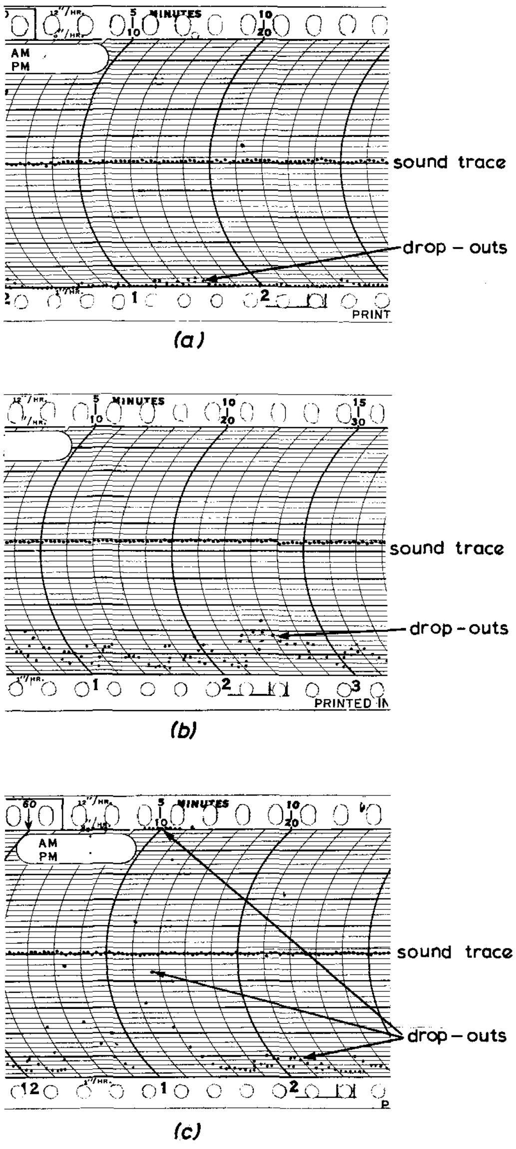

Fig. 6 - Sections of typical charts

the preceding ten seconds. Fig. 5 shows schematically the arrangement that is used. The sequence is controlled by a binary counter which is triggered, just after each sample is taken, by a microswitch linked to the mechanism of the chart recorder. The binary counter operates a relay which connects the meter either to the detected audio signal or to the signal indicating peak drop-out impairment. The relay's change of state immediately after registration of drop-out impairment also generates a pulse that discharges the peak-recording circuit.

It has been found that the pattern of dots recording drop-out impairment can readily be distinguished from the pattern recording audio level by virtue of the very gradual variations exhibited by the latter. Thus the patterns can be allowed to overlap without risk of confusion. Fig. 6 shows 15-minute sections of three such charts. Fig. 6(*a*) represents an exceptionally good performance, (*b*) a less good but acceptable performance, and (*c*) a bad performance. Note that, in (*c*), the chart contains numerous "full-scale" samples. The sound sensitivity trace can be seen in all three cases as a virtually unbroken horizontal line; one major scale division (10% of full-scale deflection) corresponds to 2 dB.

If it is required to register only drop-out information, the peak-detecting facility can be retained by means of a simple modification to the arrangement shown in Fig. 5. The modification consists of switching one component in the binary counter, to change it to a monostable circuit whose stable state corresponds to the shown state of the relay and whose unstable state lasts for only a fraction of a second. Each pulse from the microswitch then triggers the monostable circuit, thereby causing the relay to generate a pulse discharging the peak detector; at all sampling times, however, the peak detector is connected to the chart recorder.

3. MECHANICAL CONSTRUCTION

The complete drop-out meter, shown in Fig. 7, is housed in a portable case fitted with legs and carrying handles. The electronic circuits are built on standard "Minar"[2] plug-in units, two small units being required for the meter and calibration circuits respectively, and one large unit for the double power supplier. A third small unit, containing an inter-connected plug and socket, acts as an extender and allows either of the other two small units to be operated outside the case for test purposes. The whole of this "Minar" assembly can, if preferred, be mounted as a 130 mm (5.1/8 in.) panel on a standard 480 mm (19 in.) bay.

The chart recorder, inset in the top of the case, is only about 50 mm (2 in.) deep; the space beneath it, accessible from the rear, is used as a storage compartment for the probe, the mains lead, and spare charts.

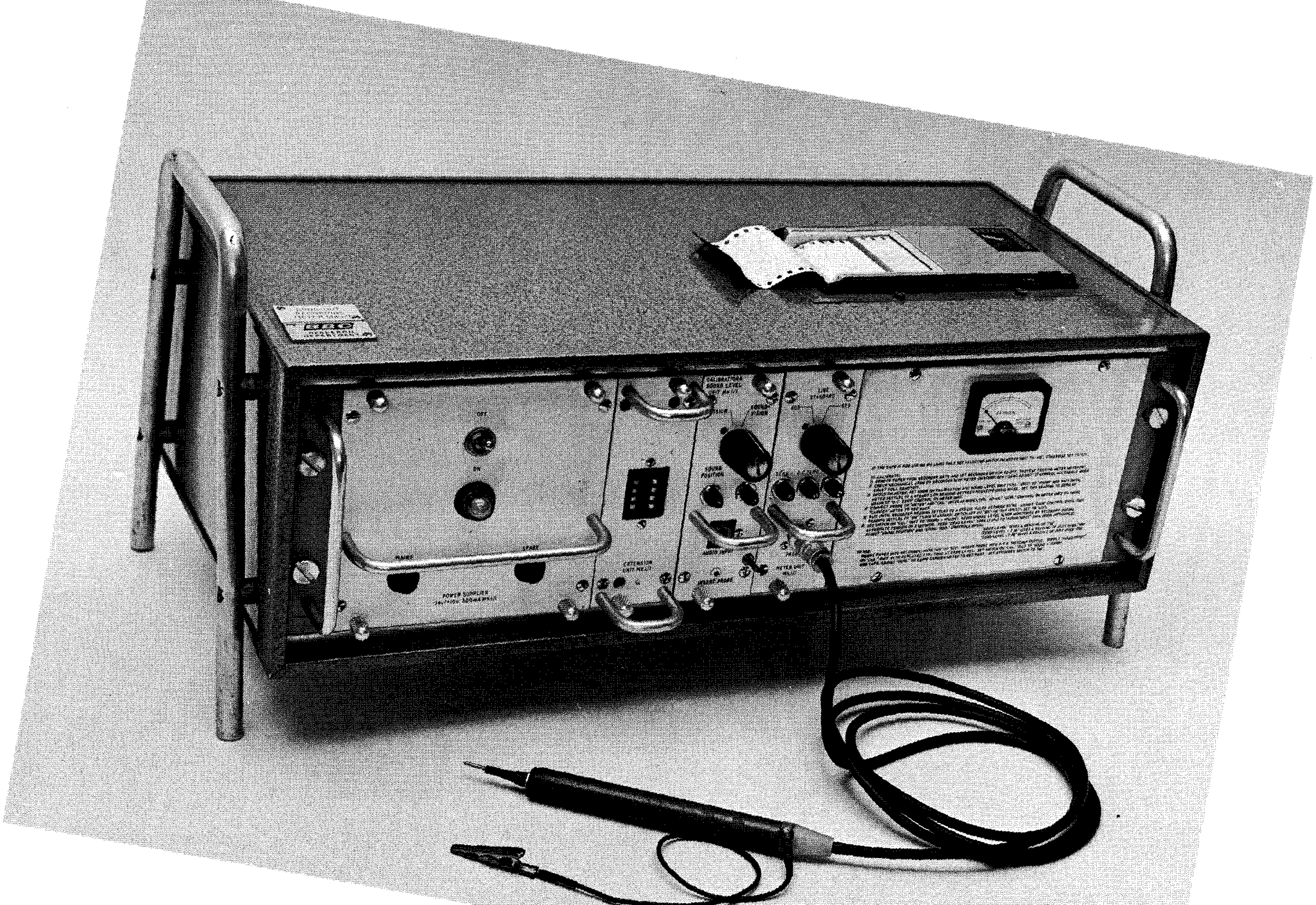

Fig. 7 - Appearance of drop-out meter

4. CHECK OF METER'S VALIDITY

The parameters of the meter are based on subjective tests that made use of simulated drop-outs occurring in definable time-sequences. After a prototype meter had been constructed, it was used to assess real drop-outs occurring in programme-bearing tapes, and its validity was checked by comparing its readings with the subjective assessments of a group of observers watching the programmes. It was considered that the meter could not properly be offered for operational trial without the performance of this test, although it was realised that the test could only reveal gross errors, since the annoyance caused by a given sequence of drop-outs depends upon the nature of the picture. To take extreme examples, a viewer watching a rapidly-moving high-key scene that interests him may fail to notice a sequence of white drop-outs that he would find very annoying in a low-key, static scene that did not interest him. In the original tests[1] with simulated drop-outs this factor was largely eliminated by imposing each sequence of drop-outs upon several different scenes and considering only the average assessment. With real drop-outs this was not practicable, and the results were correspondingly less precise.

Three programmes, of contrasting character, were each shown to two panels of ten observers under controlled conditions similar to those described in Reference 1. One panel consisted of television engineers, the other of lay viewers. At various points in the programme the observers were asked to assess drop-out impairment, in terms of the six-point impairment scale shown as a footnote on page 1.

For these tests a chart recorder producing a continuous trace was fed directly with the output of the analogue circuit. The experimental procedure was arranged so that, as the observers watched the programme, the chart recorder's stylus followed the trace it had already drawn during a preliminary run of the same recording. In this way the experimenter was able to anticipate the occurrence of peaks in the meter's output and to ask the subjects for an assessment just as peaks of various sizes occurred.

The results are summarised in Table 1. "Number of assessments" refers to the number of times an assessment was called for during each programme; "mean error" defines the mean extent by which the meter's grading of an individual peak exceeded the mean subjective grading of the same peak made by the ten observers; "r.m.s. error" refers to the same data.

It will be observed that in five of the six sets of figures the mean error is positive - that is, the meter over-estimates the severity of the drop-outs. This bias in the results can in part be attributed to the fact that these tests involved lay viewers as well as engineers, whereas the original tests upon which the meter was based used only engineers as subjects. Since lay viewers tend to be less critical of technical imperfections, their participation in the present tests might be expected to lead to "positive" errors. When attention is confined to the tests involving engineers, the mean error of all observations is only + 0·22 of a grade; the corresponding figure for the tests involving lay viewers is + 0·48 of a grade.

In addition, however, there is one aspect of the original subjective tests that could tend to cause the meter to over-estimate impairment. Because the sequences of simulated drop-outs used in these tests had to be susceptible to analysis, they were inevitably regular in their occurrence and hence, to some extent, predictable. Thus once a subject

TABLE 1

		Programme A	Programme B	Programme C
Engineers	Number of assessments	25	20	9
	Mean error	+ 0·48	- 0·15	+ 0·31
	R.m.s. error	0·66	0·44	0·44
Lay Viewers	Number of assessments	25	20	16
	Mean error	+ 0·70	+ 0·48	+ 0·12
	R.m.s. error	0·89	0·58	0·39

saw that drop-outs were occurring regularly he knew when (though not where) to look for them. This unavoidable shortcoming of the test procedure would be expected to result in a subject's being rather more aware of the drop-outs than he would have been had they occurred randomly. The meter, being based upon the results of these (original) tests, might therefore be expected to yield slightly pessimistic results when genuine, and thus random, drop-outs were assessed. The r.m.s. errors, varying from 0·39 to 0·89 of a grade, compare unfavourably with the figure of just under 0·2 of a grade obtained, prior to the meter's construction, when subjective gradings of simulated drop-outs in definable sequences were compared with predicted meter gradings. However, as already stated, this is thought to be primarily due to the influence of the programme material. Since when a tape is tested little or nothing is known of the programme material which will subsequently be recorded upon it, this form of inaccuracy is inseparable from the assessment of tape stock as such. It was therefore concluded that, within the limitations of the tests, the meter had performed well enough to justify a period of experimental service use.

5. APPLICATION OF THE METER

The drop-out meter was developed primarily as a means of rationalising the procedure for the acceptance of new tapes. Visual assessments do not form a satisfactory basis for agreement between manufacturer and user, since it is almost impossible to define minimum acceptable performance in visual terms.

A total of four meters have been constructed and have been used for an increasing proportion of tape-acceptance tests during the past eighteen months. The great majority of new tapes supplied to the BBC are now initially assessed by the meters, and are accepted if the charts show a uniformly low drop-out content throughout their length. If a chart indicates that the tape is unacceptable, a visual check is made at a part of the tape that the chart shows to be particularly bad, before the tape is rejected; this check acts as a safeguard against wrongly rejecting a tape as a result of a fault condition in the v.t.r. or the drop-out meter.

Apart from its application to acceptance testing, the meter enables the drop-out activity of a tape to be checked throughout its operational life. Since the operation of the meter involves only the amplitude of the frequency-modulated replay signal, drop-outs can be assessed during transmission, and the chart put in the same box as the tape, thus making the information readily available to future users. A specified standard of drop-out performance might also be offered (and demanded) in recorded tapes exchanged between broadcasting organisations.

6. ASSESSMENT OF CHARTS AND CHOICE OF CRITICAL DROP .

It is necessary for the assessment of charts to be reduced to a few simple rules if the meter is to fulfil its purpose of eliminating the arbitrary subjective decisions of individual operators. It might, for example, be agreed that a tape should be rejected if the chart indicated either of two situations, namely:

1. A given level of impairment exceeded for a given fraction of time.
2. A lower level exceeded for a greater fraction of time.

It must be stressed that although the meter is calibrated in terms of stated levels of impairment, this in no way dictates the threshold (or thresholds) of acceptability adopted by an organisation using the meter. Each organisation is free to choose its own threshold in accordance with its own technical standards.

Similar considerations apply to the choice of the critical drop defining the occurrence of a drop-out. Different tape manufacturers specify different values of critical drop, and v.t.r. machines differ in the degree of amplitude limiting available to suppress a drop-out. Thus, a case can be made for any value of critical drop between, say, 12 dB and 26 dB.

Mention should here be made, however, of a factor indicating the choice of a smaller value of critical drop than might at first sight seem appropriate. Some manufacturers specify that drop-out shall be assessed with a "tip penetration"* exceeding a certain minimum value. The severity of drop-out increases with decreasing tip penetration so that as a head's pole-pieces are worn down, the accompanying decrease in tip penetration results in a worse drop-out performance from tape of a given quality.** However, choosing the critical drop to be considerably less than that producing failure of limiters affords some protection against accepting tapes that would have an unacceptable drop-out performance when used with heads nearing the end of their useful life.

* "Tip penetration" is a term defining the extent to which the protruding pole-pieces of the rotating heads press into the tape as they sweep across it.

** The minimum tip penetration specified by manufacturers for tape assessment is reached well before half-way through the life of a typical head.

7. CONCLUSIONS

A meter has been developed which provides a convenient and reproducible assessment of the drop-out content and audio track sensitivity of video tapes. Extensive operational use has established the meter's acceptability to tape users.

The meter is based on simply-defined parameters and could well form the basis of an agreement among tape manufacturers and tape users, specifying acceptable standards of performance.

8. REFERENCES

1. The subjective impairment produced by drop-outs in video tape recordings. BBC Research Department Report No. T-143, Serial No. 1965/1.
2. MINAR - A miniature rack-modular system for electronic equipment. BBC Research Department Report No. A-078, Serial No. 1963/46.

APPENDIX

Circuit Details of the Meter

Fig. 8 shows the circuit of the practical meter, excluding the calibrator and the circuits associated with the monitoring of audio sensitivity.

The Limiting Detector

The transistors TR1 - TR6 constitute the limiting detector. The input signal is picked up from the v.t.r. by means of an emitter-follower probe (not shown). The meter requires an input signal level of about 0·5V peak-to-peak, if drop-outs are to be defined by a 20 dB fall in signal level; this level is readily obtainable from the output of the head-switcher in a machine of the Ampex 1000 series. Where the meter is to be used in conjunction with other types of machine it may be necessary to provide a special test-point bearing the appropriate signal. An inductor in the collector circuit gives h.f. pre-emphasis above 5 MHz to offset the fall in h.f. response exhibited by the input signal. Diode D1 and grounded-base transistor TR2 act as symmetrical clippers, and limit the signal applied to the input of TR3.

The mean collector current of TR2 is measured by a small moving-coil meter. By adjusting the preset "meter sensitivity" control it is arranged that the meter reaches a standard deflection when the input level to the limiting detector exceeds its critical input level by an amount equal to the required "critical drop". Thereafter, correct input conditions are obtained by adjusting the "sensitivity" control until the standard meter-deflection is reached.

The transistors TR3 and TR4 form a long-tailed pair. The defined emitter current and the collector load resistors are so related that when there is no input signal, and the current is equally divided between the two transistors, neither collector load develops enough standing voltage to turn on TR5 or TR6. The potential of the common collector connection of TR5 and TR6 constitutes the output of the limiting detector. In the absence of signal, therefore, the output potential is held, by diode D2, near the value defined by Zener diode D3. However, when the input to TR3 causes a sufficient voltage swing to appear at the bases of TR5 and TR6, these transistors are alternately bottomed during successive half-cycles of the input signal, and the output potential is held near negative supply voltage. The range of input levels producing intermediate values of output potential is about 2 dB. The detector is balanced by adjusting the input level to lie within this 2 dB range, and then adjusting the d.c. potential on the base of TR4 until the ripple on the detectors output waveform contains a minimum amount of input-frequency fundamental.

The functioning of the limiting detector during a 5 μs drop-out is represented by waveforms 1 and 2 in Fig. 8.

The Current-Impulse Generator

This section of the meter comprises transistors TR7 to TR11, and produces, from each drop-out, an impulse lasting about a thousand times as long as the drop-out itself. This technique obviates the difficulty of designing an analogue circuit whose ratio of charging to discharging time is $> 10^6$.

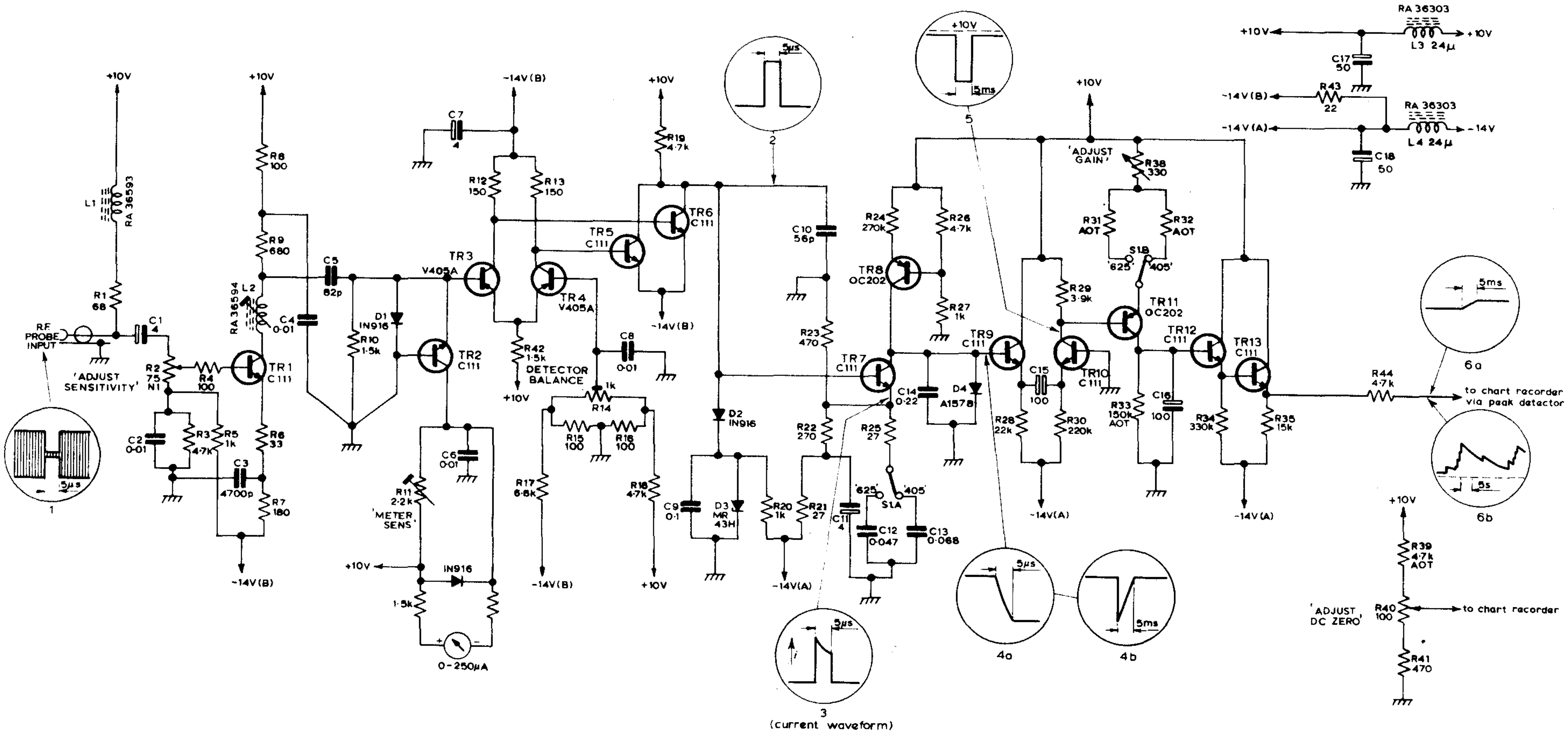

Fig. 8 - Circuit diagram of meter

The voltage impulse (Waveform 2) applied to the base of TR7 turns this transistor on, and the RC network in the emitter circuit causes its current waveform (Waveform 3) to exhibit the required initial peak (see Section 2.2); the value of the capacitor is switched in accordance with the relevant line standard. The duration of the impulse is expanded in the collector circuit of TR7. The current impulse causes the potential at this point to fall by one or two volts from its quiescent value as the capacitor is discharged (Waveform 4a). The transistor TR8 supplies a constant current that tends to recharge the capacitor but is about a thousand times smaller than the mean value of i during the discharging impulse. Consequently, for a 5 μs drop-out, the potential takes about 5 ms to regain its original quiescent value (Waveform 4b); this quiescent value is stabilized at about + 0·5 volts by means of the diode D4 which is held in a barely conducting state by the current from TR8.

The transistors TR9 and TR10 detect the time for which the potential across C14 is not at its equilibrium value of 0·5V. The circuit, which is a variant of the long-tailed pair, obviates the need for d.c. adjustment. Under quiescent conditions the respective emitter resistances of TR9 and TR10 ensure that TR10 draws only about a tenth as much current as TR9. When a negative pulse is applied to the base of TR9, however, the large capacitor coupling the emitters of the two transistors causes TR9 to be cut off, and the current previously drawn by it to be transferred to TR10, whose collector waveform is shown in Waveform 5.

The voltage pulse across the collector resistor of TR10 turns on TR11, whose collector current supplies the analogue circuit; the gain of TR11 is switched according to the relevant line standard. The small current drawn by TR10 under quiescent conditions does not develop enough voltage across its collector resistor to turn on TR11.

The Analogue Circuit

This comprises the parallel combination of 150 kΩ and 100 μF, together with the double emitter-follower, TR12 and TR13. Each current impulse produces a positive-going ramp (Waveform 6a); between impulses the circuit discharges exponentially with a 14-second time constant (Waveform 6b).

At the time at which this circuit was designed, field-effect transistors were not available cheaply. However, a field-effect transistor (used in place of the emitter-follower circuits) would, by virtue of its higher input impedance, allow a much smaller capacitor to be used in the analogue circuit; it might then be possible to simplify the current-impulse generator by omitting transistors TR8 to TR11, and connecting the analogue circuit directly to the collector of TR7.

JMP

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